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Review article

A review on production and characterization of compost from flower waste and its role in enhancing soil fertility

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ABSTRACT

India generates an estimated 8 million tonnes of floral waste annually, mainly from religious places, festivals, weddings, floriculture, and commercial flower markets. With approximately 108,000 temples and mosques, large quantities of flowers are offered daily and are often discarded into rivers, lakes, or landfills after use. Improper disposal of floral waste contributes to foul odors, greenhouse gas emissions, water pollution, eutrophication, and ecological degradation, with waste generation increasing significantly during major festivals. Despite these challenges, floral waste is a biodegradable biomass rich in organic matter, cellulose, lignocellulosic compounds, essential oils, natural pigments, and other bioactive constituents, making it a valuable renewable resource. Instead of being treated as waste, it can be converted into a range of value-added products, including compost, vermicompost, biofertilizers, biogas, biofuels, natural dyes, essential oils, incense sticks, soaps, handmade paper, and eco-friendly Holi colours. Such resource recovery supports sustainable waste management while promoting a circular economy. Among the available recycling methods, vermicomposting has emerged as one of the most efficient, economical, and environmentally friendly approaches for recycling floral waste into nutrient-rich organic manure. The integration of rotary drum composting as a pre-composting step accelerates decomposition, improves substrate stabilization, and enhances vermicomposting efficiency. This integrated approach not only reduces environmental pollution but also improves soil fertility, supports sustainable agriculture, and generates livelihood opportunities, particularly for women and rural communities. This review highlights recent advances in floral waste management through composting and vermicomposting, with particular emphasis on rotary drum composting technology as an effective strategy for sustainable floral waste utilization in India.

1. Introduction

The amount of solid waste is rising quickly because of rapid urbanization, industrial growth, and a growing population in India. India generates 133,760 tonnes of waste each day (Yadav and Garg, 2011). Municipal waste consists 70% of organic waste which includes vegetables, tree leaves, fruits, floral waste and kitchen (Potdar et al., 2016). Municipal solid waste mixes with waste plastic, making it hard to separate plastic from organic waste. This takes a lot of time and adds to costs.

Flower waste is a significant component of organic waste generated worldwide from floriculture industries, religious activities, festivals, weddings, hotels, and flower markets. Although precise global estimates are limited, studies indicate that a substantial proportion of flowers produced globally become waste due to perishability, post-harvest losses, unsold inventory, and disposal after single use (Agrawal et al., 2024).

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The European Union accounts for approximately 44% of global flower production, making it one of the largest contributors to floral residues and waste streams. In many developing countries, including India and Sri Lanka, up to 40% of flower production remains unsold and eventually becomes waste because of inadequate storage and transportation facilities. The global cut-flower industry is dominated by a few major producing and exporting countries. The Netherlands holds the largest share, contributing approximately 52% of global cut-flower production and trade, making it the world's leading floriculture hub. It is followed by Colombia (15%), Ecuador (9%), and Kenya (7%), which are among the major exporters of cut flowers to international markets. Other notable contributors include Belgium (3%) and Ethiopia (2%), while Malaysia, Italy, Germany, and Israel each account for approximately 1% of global production. The dominance of these countries is attributed to favorable climatic conditions, advanced cultivation technologies, efficient supply chains, and strong export-oriented floriculture industries (Agrawal et al., 2024).

Fig. 1 Pictorial view of Flower waste (Kumar Gupta et al., 2024)

The main sources of flower waste are religious places like temples, mosques, churches, and gurudwaras, along with markets, wedding ceremonies, and various festivals. Flower waste can be collected separately from these sources. Since it doesn't need to be sorted, this will save time and money. The amount of sorted flower waste is about 300 tonnes per day, with Surat city producing 1.5 tonnes per day, which is collected separately at a flower waste collection center (Sharma and Yadav, 2017). In India, flower waste generation is closely associated with the distribution of floriculture production across states. Although official state-wise floral waste statistics are unavailable, major flower-producing states are expected to contribute the highest quantities of flower waste. Tamil Nadu is the leading producer, accounting for approximately 21–24% of national flower production, followed by Madhya Pradesh, Karnataka, West Benga, and Andhra Pradesh Fig 2: shows state wise flower waste generation Chaudhary et al., 2024). Other significant contributors include Gujarat, Maharashtra, Odisha, Telangana, and Uttar Pradesh. In addition to production-related waste, states with major religious centres such as Uttar Pradesh, Uttarakhand, Maharashtra, Tamil Nadu, and West Bengal generate substantial quantities of floral waste from temples, festivals, and ceremonial activities. Consequently, these regions present significant opportunities for flower waste valorization through composting.

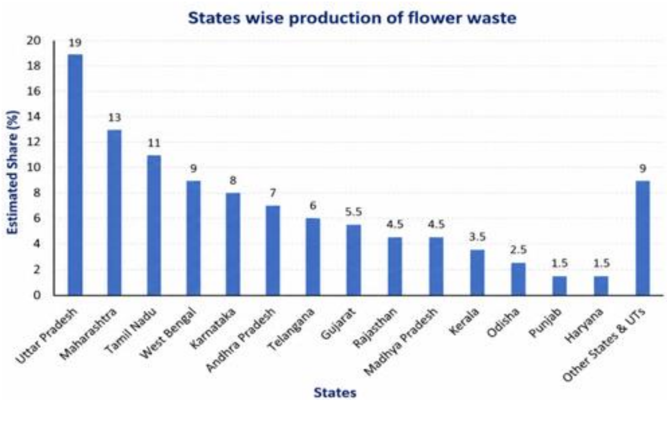

Fig. 2 Flower waste state wise generation in India

Flower waste is rich in both macronutrients such as Nitrogen, Phosphorus, Pottassium, Calcium as well as micronutrients like Iron, Manganese, Zinc and Copper which can be repurposed for agriculture use by transforming it into compost (Sharma et al., 2017). MSW consists of 21-64% cellulose, 5-22% hemicellulose and 3-28% lignin (Waghmode et al., 2018).

Composting is a widely used technique for converting organic waste into rich, nutrient-filled soil. This process entails the biological decomposition and stabilization of organic materials, producing heat that elevates the temperature throughout the process. The result is a stable product that is free from pathogens and plant seeds, making it safe for land application. These organic fertilizers are eco-friendly and do not harm natural resources. They enhance soil fertility, promoting healthier plant growth. The use of organic fertilizers also raises the levels of soil organic matter and increases microbial activity within the soil (Bhati et al., 2021) In composting, bulking agents play a vital role in the decomposition of organic material. They function as buffers,

2. Different technologies for Flower Waste Composting

The conversion of flower waste into compost is an environmentally sustainable approach that transforms biodegradable floral residues into nutrient-rich organic amendments. Various composting technologies have been employed to enhance decomposition efficiency, nutrient conservation, and compost quality. The selection of an appropriate composting method depends on the characteristics of the flower waste, available infrastructure, processing time, and desired compost quality.

2.1 Traditional Composting

Traditional composting is one of the oldest and most widely practiced methods for managing organic waste. In this process, flower waste is accumulated in pits or heaps and allowed to decompose naturally through the activity of indigenous microorganisms. The waste is typically mixed with cattle manure, crop residues, or soil to improve the carbon-to-nitrogen (C) ratio and microbial activity. Periodic turning is performed to enhance aeration and maintain uniform decomposition (Ayilara et al., 2020; Kumar et al., 2020).

The composting process generally lasts between 3 and 6 months depending on environmental conditions. Although traditional composting is simple and cost-effective, it often requires a longer decomposition period and may result in nutrient losses if not properly managed. Nevertheless, it remains a suitable method for rural areas and small-scale waste management systems.

2.2 Aerobic Composting

Aerobic composting involves the decomposition of flower waste in the presence of oxygen by aerobic microorganisms such as bacteria, fungi, and actinomycetes. During the process, microorganisms oxidize organic matter, generating heat, carbon dioxide, water, and stabilized humus (Kumari et al., 2021).

The process occurs in four stages:

a) Initial mesophilic phase (20–40°C)
b) Thermophilic phase (45–70°C)
c) Cooling phase
d) Maturation phase

The thermophilic stage is particularly important because it destroys pathogens, weed seeds, and harmful microorganisms. Aerobic composting generally produces mature compost within 6–12 weeks, significantly faster than traditional composting (Abdel-Shafy and Mansour, 2018; Kumari et al., 2021). Studies have reported that aerobic composting of flower waste improves nutrient availability and enhances the quality of the final compost through accelerated organic matter degradation (Abdel-Shafy and Mansour, 2018).

aiding in maintaining the pH level between 6 and 8 during the initial stages when organic acids develop. Bulking agents also help uphold aerobic conditions and keep the moisture content between 50 to 60% in the piles during the degradation process. Excess moisture can lead to leachate, hindering the composting process by diminishing oxygen availability and porosity(Bhati et al., 2021; Yadav et al., 2022). The blossoms wind up decaying in the nearby body of water. Thousands of temple flowers eventually decay in the rivers.

2.3 Vermicomposting

Vermicomposting is a bio-oxidative process that utilizes earthworms and microorganisms to convert flower waste into nutrient-rich vermicompost. Commonly used earthworm species include *Eisenia fetida, Eudrilus eugeniae*, and *Perionyx excavates*(Amalina et al., 2022; He et al., 2016).

Earthworms fragment the organic material, increase surface area for microbial action, and accelerate decomposition. Flower waste is usually pre-decomposed for 10–15 days before introducing earthworms to avoid excessive heat generation.

Vermicompost possesses several advantages:

• Higher nutrient availability
• Increased microbial activity
• Enhanced humic substances
• Improved soil structure
• Greater plant growth-promoting effects

Numerous studies have demonstrated that vermicompost derived from flower waste contains elevated levels of nitrogen, phosphorus, potassium, micronutrients, and beneficial microorganisms, making it an excellent organic fertilizer for sustainable agriculture (Agarwal and Jain, 2024).

2.4 Microbial-Assisted Composting

Microbial-assisted composting involves the deliberate inoculation of beneficial microorganisms to accelerate decomposition and improve compost quality. Microbial inoculants commonly include: Bacillus spp., Pseudomonas spp, Azotobacter spp, Trichoderma spp, Aspergillus spp.
(Agrawal et al., 2024).

These microorganisms produce enzymes such as cellulases, ligninases, proteases, and pectinases that facilitate the breakdown of complex organic compounds present in flower waste (Klamer et al., 2006).

Microbial inoculation offers several benefits: Faster decomposition rates, reduced composting duration, improved nutrient mineralisation, and enhanced pathogen suppression, Increased compost maturity (Gorasiya and Faldu, 2023).

Recent research suggests that microbial consortia are more effective than single microbial strains due to synergistic interactions among different microbial groups. The integration of flower waste composting with microbial inoculants has emerged as a promising strategy for producing high-quality biofertilizers (Gorasiya and Faldu, 2023).

2.5 Factors affecting compost quality

The quality of flower waste compost is influenced by several physicochemical and biological factors.

2.5.1 Carbon-to-nitrogen ratio (C/N Ratio)

The C ratio is one of the most critical parameters controlling microbial activity. An initial C ratio of 25:1 to 30:1 is generally considered optimal for efficient composting. Excess carbon slows decomposition, whereas excess nitrogen may lead to ammonia volatilization and odor generation (Pan et al., 2012).

2.5.2 Moisture content

Microorganisms require adequate moisture for metabolic activities. Moisture levels between 50 and 60% are generally optimal. Excess moisture creates anaerobic conditions, while insufficient moisture limits microbial growth and decomposition (Sharma et al., 2018).

2.5.3 Temperature

Temperature regulates microbial succession and decomposition rates. Thermophilic temperatures (45–65°C) promote rapid degradation of organic matter and pathogen elimination. Sustained temperature fluctuations may negatively affect compost stability (Bhati et al., 2021).

2.5.4 Aeration

Adequate oxygen supply is essential for aerobic microbial metabolism. Poor aeration can lead to anaerobic decomposition, unpleasant odors, and reduced compost quality. Regular turning of compost piles improves oxygen diffusion and decomposition efficiency (Meena et al., 2021).

2.5.5 pH

The optimal pH range for composting is between 6.5 and 8.0. Extreme pH values inhibit microbial activity and reduce nutrient availability. During composting, pH typically fluctuates due to organic acid formation and ammonia production (Amir et al., 2003; López et al., 2021).

2.5.6 Particle Size

Smaller particle sizes increase the surface area available for microbial colonization and decomposition. However, excessively fine particles may reduce porosity and restrict airflow (Eades et al., 2020; Mishra and Yadav, 2022).

2.5.7 Microbial Community Structure

The diversity and abundance of microorganisms determine the efficiency of organic matter degradation. Beneficial microbial populations contribute to nutrient cycling, pathogen suppression, and compost stabilization (Aguilar-Paredes et al., 2023a, 2023b; Andraskar et al., 2021).

2.5.8 Composting duration

Adequate curing and maturation periods are essential for producing stable compost. Immature compost may contain phytotoxic compounds that negatively affect plant growth and soil microorganisms (Lalremruati et al., 2021).

3. Flower waste management

Flower waste management has emerged as an important environmental concern due to the large quantities of floral residues generated from religious activities, weddings, festivals, flower markets, and the floriculture industry (Baeta-Hall et al., 2005). In India alone, approximately 8 million tonnes of floral waste are generated annually, much of which is disposed of in landfills, rivers, and other water bodies, leading to water pollution, foul odors, eutrophication, and greenhouse gas emissions. Sustainable management of flower waste involves collection, segregation, and conversion into value-added products through various biological and physicochemical processes. Among the available approaches, composting and vermicomposting are the most widely adopted techniques because they transform biodegradable floral residues into nutrient-rich organic fertilizers that improve soil fertility and support sustainable agriculture.

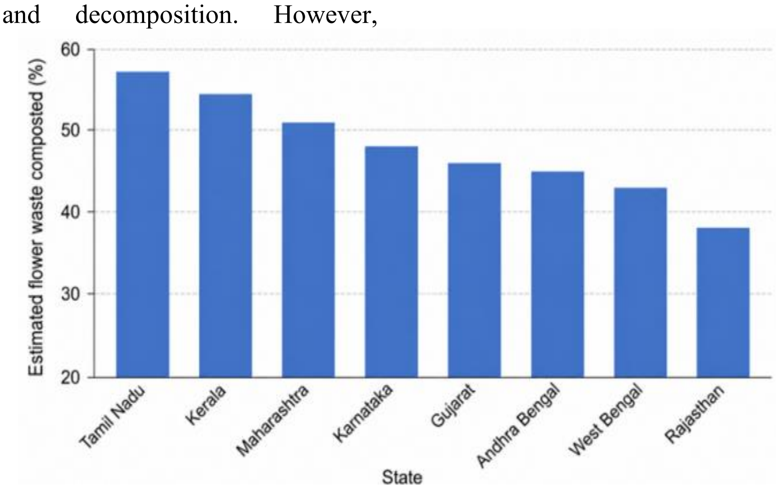

Fig. 2 State wise conversion of flower waste in to compost

Fig. 2 represents flowers recycled to compost (KVIC – Khadi and Village Industries Commission). other management strategies include anaerobic digestion for biogas production, extraction of natural dyes and essential oils, production of incense sticks and handmade paper, biochar generation, and recovery of bioactive compounds (Azim et al., 2018). Recent studies have emphasized the importance of adopting circular economy principles for flower waste valorization, where waste materials are converted into useful products rather than being discarded. Such approaches not only reduce environmental pollution but also create economic opportunities and contribute to sustainable waste management systems. Therefore, effective flower waste management represents a promising strategy for resource recovery, environmental protection, and sustainable agricultural development. Table 1 shows different techniques of flower waste management (Popich et al., 2026).

4. Vermicomposting process of flower waste

Flower waste vermicomposting is an eco-friendly and sustainable biological process in which discarded flowers from temples, religious places, markets, hotels, and households are converted into nutrient-rich organic manure through the combined action of earthworms and microorganisms. The process begins with the collection and segregation of flower waste, ensuring the removal of non-biodegradable materials such as plastic threads, polythene bags, metal wires, and synthetic decorations (Ishii et al., 2000). The collected flower waste is then chopped into small pieces (2–5 cm) to increase the surface area available for microbial decomposition. Since fresh flower waste may generate heat and release volatile compounds harmful to earthworms, a pre-composting stage of 10–15 days is recommended. During this stage, flower waste is mixed with cow dung, usually in a ratio of 1:1 or 2:1 (flower waste:cow dung), and allowed to partially decompose under aerobic conditions. After pre-composting, vermibeds are prepared using a base layer of gravel or sand for drainage, followed by a layer of dry leaves or straw to enhance aeration. The pre-decomposed flower waste mixture is then spread over the bed (Das and Deka, 2021). Earthworms such as *Eisenia fetida*, *Eudriluseugeniae*, or *Perionyx excavatus* are introduced at a density of approximately 1–2 kg m^{-2} (about 1000–2000 worms m^{-2}). The vermibeds are maintained under shaded conditions with a moisture content of 60–80% and a temperature range of 20–30°C, which are optimal for earthworm growth and microbial activity. Moisture is maintained through periodic sprinkling of water, while excessive watering is avoided to prevent anaerobic conditions. The pH is generally maintained between 6.5 and 8.0 (Patel et al., 2024). During the vermicomposting period, earthworms ingest the decomposing flower waste, grind it in their gizzard, and excrete nutrient-rich casts that contain enhanced levels of nitrogen, phosphorus, potassium, beneficial microorganisms, and plant growth-promoting substances. The vermicomposting process usually takes 45–60 days, depending on the composition of the flower waste and environmental conditions. As decomposition progresses, the organic carbon content decreases while nutrient availability increases, leading to a reduction in the C:N ratio from around 30–50:1 to 10–20:1, indicating compost maturity (Patel et al., 2024).

The finished vermicompost is characterized by a dark brown to black color, granular structure, earthy odor, and high nutrient content. Typical nutrient concentrations range from 1.5–2.5% nitrogen, 0.8–1.5% phosphorus, and 1.0–2.0% potassium. Harvesting is carried out by separating earthworms from the compost through light exposure or sieving methods (Waghmode et al., 2018). The final vermicompost can be used as an organic fertilizer and soil conditioner in agricultural crops, horticultural plants, nurseries, and home gardens. Flower waste vermicomposting not only reduces environmental pollution caused by indiscriminate disposal of floral residues but also supports waste recycling, sustainable agriculture, and circular economy principles by transforming a problematicorganic waste into a valuable agricultural input. Table **2** shows physical, chemical, biological parameter and their significance(Srivastav and Kumar, 2021).

5. Flower waste composting through rotary drum composter

For composting floral debris, a rotary drum composter measuring 1.20 m in length, 0.80 m in diameter, and 0.6 m3 in metal thickness was utilized. Anticorrosive paint was applied to the entire rotating drum assembly to stop it from rusting (Kalamdhad and Kazmi, 2009). Four metal rollers, one metal support, and one handle were used to secure the drum for rotation. To fully mix the waste mixture, 40 mm angles were longitudinally welded in the rotational drum (Kalamdhad et al., 2009). The drum was perforated with two holes to allow the leachate to flow out. Using the plastic bucket, the waste mixture's composition was fed into the drum(Dutta & Kumar, 2021).

The door was left open and the drum was rotated every four and a half days, which helped to keep the aerobic environment inside the drum stable (Singh and Kalamdhad, 2013).

Every combination underwent a double trial, and the average result was provided. A 500–600 g sample was taken from the top, middle, and bottom of the drum and placed in an oven set at 105 ± 2 °C for 24–72 hours. The sample was then ground and sieved through a 0.2 mm sieve for additional physico-chemical examination(CR et al., 2025). Table 3 shows physicochemical properties of flower waste in rotary drum composting.

6. Advantages

Flower waste has several socioeconomic, agricultural, and environmental benefits. It reduces pollution and landfill accumulation by turning enormous amounts of waste from temple and market flowers into valuable organic manure, making it an effective technique for waste reduction and resource recovery (Shen et al., 2023). In addition to supplementing the soil with vital nutrients like nitrogen, phosphate, and potassium, the compost created improves the soil's structure, porosity, and ability to retain water. Composting is an environmentally benign and sustainable method that stops synthetic dyes and chemicals from leaking into surrounding soil and water bodies and lowers greenhouse gas emissions linked to open dumping (Srivastav et al., 2023). Additionally, it is an inexpensive and straightforward technology that may be used with locally accessible materials at the home, institutional, or municipal levels (Popich et al., 2026). To boost its market value and open doors for small-scale business ventures and community-based waste management, the compost can also be enhanced with micronutrients or biofertilizers. Composting, when done correctly, improves sanitation and aesthetics surrounding flower markets and temples by reducing pathogen load and controlling odour (Elorrieta et al., 2002). Temples all around India produce a significant amount of floral debris every day, which can be efficiently used to make natural colours for the textile industry. Carotenoids like lutein and flavonoids are abundant in flower petals, such those of marigolds These compounds can be isolated and applied to natural fibers like cotton, wool, and silk. It has been discovered that pretreatment of textiles with low quantities of plant extracts and metal mordants results in consistent, vibrant, and long-lasting colours (Andraskar et al., 2021).

Similarly, there is great potential for extracting natural dye from the petals of saffron flowers. Under various pH levels, both with and without mordants, the dyes produced acceptable colour shades with good light-fastness and washing qualities when applied to fine fabrics such as Pashmina wool. This shows a strong link between the fiber molecules and the natural colours,

which qualifies them for use in sustainable textile and their applications.
environmental protection and health safety become more important concerns (Albrecht et al., 2008).
Natural mordants like alum, or ferrous sulfate has shown that floral wastes like marigold and hibiscus have a high dyeing potential on cotton and cotton-silk blended materials. Natural dye pigment recovery and preservation from household and temple flower wastes have been further enhanced by sophisticated extraction methods such spray drying and ultrasonic-assisted extraction.
Using the leftover residue after dye extraction has been shown to be abundant in nutrients and organic matter, which can be used as raw materials to make compost or biofertilizer, supporting a Negative and allergenic consequences of synthetic dyes, the usage of natural dyes is becoming more popular as circular economy and zero-waste strategy (Reyes-Torres et al., 2018).
Waste from temple flowers can be used to make environmentally safe natural dyes, making it a significant renewable resource. Its use contributes to resource recovery, environmental conservation, and the reduction of solid waste formation in addition to offering a sustainable substitute for synthetic dyes. The conversion of floral wastes into natural dye supplies promotes a cleaner and greener environment by being consistent with the concepts of sustainability, waste utilization and the circular economy (Reyes-Torres et al., 2018).

Table 2 Changes in physicochemical properties during vermicomposting of flower waste

Category	Parameter	Optimum Range / Typical Value	Significance
Physical	Temperature	20–30°C	Promotes earthworm activity and decomposition.
	Moisture Content	60–80%	Essential for earthworm survival and microbial growth.
	pH	6.5–8.0	Suitable range for earthworms and beneficial microbes.
	Bulk Density	0.5–0.8 g/cm^3	Indicates porosity and aeration of the compost.
	Electrical Conductivity (EC)	1–4 dS/m	Reflects soluble nutrient concentration.
	Aeration	Good	Prevents anaerobic conditions and foul odor formation.
Chemical	Organic Carbon (%)	Initial: 35–50; Final: 15–25	Decreases due to microbial degradation of organic matter.
	Total Nitrogen (%)	Initial: 0.5–1.0; Final: 1.5–2.5	Increases due to mineralization and earthworm activity.
	Available Phosphorus (%)	Initial: 0.2–0.5; Final: 0.8–1.5	Enhanced through microbial solubilization.
	Available Potassium (%)	Initial: 0.5–1.0; Final: 1.0–2.0	Released from decomposing organic residues.
	C:N Ratio	Initial: 30–50:1; Final: 10–20:1	Indicator of compost maturity and stabilization.
Biological	Earthworm Biomass Increase	50–150%	Reflects successful vermicomposting conditions.
	Cocoon Production	2–5 cocoons/worm/week	Indicates reproductive efficiency of earthworms.
	Microbial Population	10^6–10^8 CFU/g	Contributes to decomposition and nutrient cycling.
	Enzyme Activity	Increased during vermicomposting	Enhances breakdown of organic matter and nutrient release

Table 3 Changes in physicochemical properties during rotary drum composting of flower waste

Parameter	Initial Flower Waste	Final Compost
Moisture Content (%)	70–85	30–40
Organic Carbon (%)	40–50	20–30
Total Nitrogen (%)	0.8–1.2	1.5–2.2
Available Phosphorus (%)	0.3–0.6	0.8–1.4
Available Potassium (%)	0.5–1.0	1.2–2.0
C:N Ratio	30–40	12–18
Temperature (° C)	Ambient	55–70 (thermophilic phase)
Compost Stability	Unstable	Stable and Mature

7. Disadvantage

However, there are several drawbacks to composting flower waste. Floral waste's diverse composition frequently contains artificial materials like plastic ribbons, threads, and ornaments, which impede the breakdown process and necessitate time-consuming pre-sorting(Abdel-Shafy and Mansour, 2018). Certain floral parts, especially woody stems or petals that are high in lignin and pigments, break down more slowly, lengthening the composting time. Furthermore, the carbon-to-nitrogen ratio of flower waste may be unbalanced, requiring co-composting with nitrogen-rich materials such as cow dung or kitchen waste in order to obtain the best decomposition (Elango and Govindasamy, 2018). For composting to be effective, variables like temperature, aeration, and moisture must be regularly monitored; otherwise, odour issues or vector infestation may result. Significant space is also needed for large-scale composting operations, and compost stabilization takes weeks to months.

8. Challenges

Flower waste management faces several technical, environmental, and economic challenges. Improper disposal of floral residues into rivers, water bodies, and landfills remains a major concern, contributing to pollution and ecosystem degradation. The high moisture content of flower waste can create anaerobic conditions, resulting in leachate generation and odor problems during composting(Elango & Govindasamy, 2018). Additionally, the presence of lignocellulosic materials and antimicrobial compounds such as phenolics and essential oils can slow microbial degradation and prolong composting periods(Andraskar et al., 2021). Efficient composting also requires maintaining an optimal carbon-to-nitrogen ratio, often necessitating the addition of bulking agents such as sawdust or cow dung. Other challenges include poor source segregation, lack of dedicated processing infrastructure, inconsistent compost quality, and limited commercialization opportunities. Addressing these constraints through improved waste collection systems, advanced composting technologies, microbial inoculants, and policy support is essential for sustainable flower waste valorization(He et al., 1995). Despite its potential as an environmentally friendly waste management technique, composting flower waste has a number of drawbacks. Flower waste's high moisture content and quick biodegradability are a big problem since, if left unchecked, they can cause anaerobic conditions, leachate production, and unpleasant aromas. Frequently combined with flower debris, non-biodegradable items like plastics, threads, and artificial ornaments make composting more difficult and may need to be separated by hand. The availability of floral waste might fluctuate seasonally and during festivals, which can potentially impede ongoing compost manufacturing. Furthermore, flowers with high lignin and pigment content may slow down decomposition or have an impact on the final compost's quality.

9. Conclusion and future prospects

The increasing generation of flower waste worldwide, particularly in countries with large religious, cultural, and floriculture activities such as India, necessitates the development of sustainable waste management strategies. Flower waste possesses significant potential for valorization due to its rich organic matter, nutrients, pigments, essential oils, and bioactive compounds. Future research should focus on developing integrated biorefinery approaches that combine composting, vermicomposting, biofertilizer production, biochar generation, biogas production, and extraction of value-added products from floral residues.

Advancements in composting technologies, including rotary drum composting, in-vessel composting, and microbial-assisted composting, are expected to improve processing efficiency, reduce composting time, and enhance compost quality. The application of microbial consortia, plant growth-promoting rhizobacteria (PGPR), and enzyme-producing microorganisms can further accelerate decomposition and increase nutrient availability in the final compost product.

The integration of flower waste compost with beneficial microbial inoculants offers promising opportunities for developing multifunctional biofertilizers that enhance soil fertility, improve nutrient-use efficiency, and promote sustainable crop production. Furthermore, the adoption of circular economy principles can facilitate the conversion of flower waste into commercially valuable products such as natural dyes, essential oils, antioxidants, biodegradable packaging materials, and eco-friendly incense products.

Digital technologies, artificial intelligence, and smart waste management systems may also play a significant role in optimizing flower waste collection, segregation, processing, and utilization. Government support, public awareness programs, and public–private partnerships will be crucial for establishing decentralized composting facilities and promoting large-scale flower waste recycling initiatives.

Future studies should focus on standardizing compost quality parameters, evaluating the long-term effects of flower waste compost on soil health, assessing economic feasibility at commercial scales, and developing innovative technologies for resource recovery. Such efforts will contribute to environmental sustainability, waste reduction, circular bioeconomy development, and climate-resilient agriculture.

The increasing generation of flower waste from temples, religious ceremonies, flower markets, hotels, and households presents a significant environmental challenge in India due to its improper disposal in landfills and water bodies. Conventional disposal methods contribute to greenhouse gas emissions, unpleasant odors, and water pollution while wasting valuable organic resources. Composting and vermicomposting have emerged as environmentally sustainable approaches for converting flower waste into nutrient-rich organic manure. Among the available composting technologies, rotary drum composting offers several advantages, including rapid degradation, efficient aeration, uniform mixing, reduced composting time, and improved pathogen reduction. The partially stabilized material produced through rotary drum composting provides an ideal substrate for subsequent vermicomposting, where earthworms further enhance nutrient availability, humification, microbial diversity, and overall compost quality.

The integration of rotary drum composting with vermicomposting represents a promising two-stage waste management strategy that combines the speed of mechanical composting with the biological refinement provided by earthworms. This integrated approach reduces the overall processing time from approximately 90–120 days in conventional methods to about 45–60 days while producing mature compost with lower C ratio, higher concentrations of nitrogen, phosphorus, potassium, beneficial microorganisms, and improved physical properties. Furthermore, the process supports circular economy principles by converting floral waste into valuable biofertilizers, reducing dependence on chemical fertilizers, minimizing landfill disposal, and promoting sustainable agriculture. Future research should focus on process optimization, microbial inoculation, reactor-scale studies, life-cycle assessment, techno-economic analysis, and commercialization strategies to facilitate large-scale adoption of integrated flower waste management systems.

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Author Contributions

Deepika Mishra conceptualized the study, prepared the draft of the article, and conducted the formal analysis. **Roshini Bajaj** assisted in drafting the article and contributed to the formal analysis. **Pakkala Ruchitha** has also conceptualized the study, prepared the draft of the article. **Jiwan Singh** reviewed, edited, validated the manuscript, and supervised the overall study. All authors read and approved the final version of the manuscript.

Conflict of Interest

There is no conflict of interest declared by authors**.**

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